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Southwestern
Region,
October 1980

Western Spruce Budworm Suppression and Evaluation Project Using Carbaryl

Final Report, 1977-79, New Mexico

JAN 4 1984

ROCKY MOUNTAIN STATION

Cover: Photograph taken by Bill Jack Rodgers, University of California, Los Alamos Scientific Laboratory, Office of Public Information, Los Alamos, New Mexico 87544.

United States
Department of
Agriculture

**Forest
Service**

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Abstract

In 1977, carbaryl was aerially applied to a new and increasing western spruce budworm, *Choristoneura occidentalis* Free., outbreak in an isolated mountain range in New Mexico. Sampling results showed that the larval densities were drastically reduced and remained low 3 years following treatment. In a comparable untreated check area, larval densities were significantly higher. The average density of egg masses per meter square of foliage confirmed the results of the larval sampling, and indicated that larval densities would be low in 1980. Relative to the check area, the density of larvae was low in the treated area in 1980, although larval densities reached sufficient levels in portions of three subunits to cause light to moderate defoliation. Tree defoliation in the treatment area, however, remained well below levels recorded in the untreated area.

This project was the first attempt to evaluate multi-year effects of an aerially applied chemical on this defoliator. The results indicate that satisfactory suppression of a new and increasing outbreak can be achieved for at least 4 years.

No lasting adverse effects of the aerial application of carbaryl could be identified for aquatic organisms and birds.

Most species of western spruce budworm parasites were not significantly affected by the treatment program. The percent parasitism by some species increased and others decreased during the 3 years of sampling.

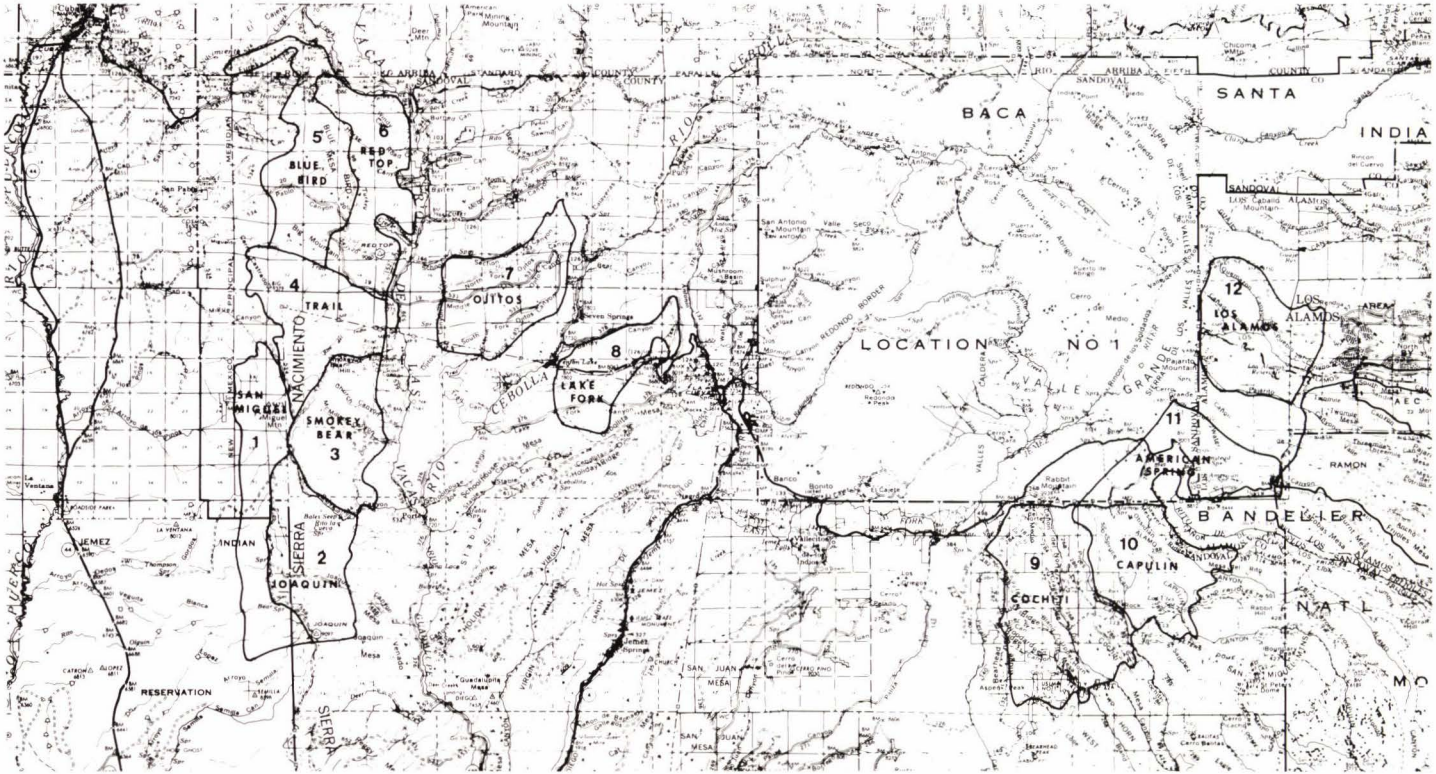


Figure 1.—Location of treated (1–6) and untreated (7–12) subunits, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

computed by averaging the larval density on each sample branch per tree, and then averaging the 3-tree means.

Sampling for Egg Masses In late July, two branches (70 cm in length) were cut from opposite sides of sample trees on permanent plots. The length and width of each branch was used to calculate foliated branch area.

Foliage from all branches were examined under ultra-violet light for egg masses. Needles bearing egg masses were classed as from current year's foliage, or a previous year, and kept separate in labeled pill boxes. New and old egg masses were separated under a stereo-microscope. All egg masses on current year's foliage were classed as new, and their characteristics formed the basis for aging those egg masses found on the previous year's foliage.

Analysis of Larval and Egg Mass Densities Estimates of larval densities, expressed as number of larvae per 100 live buds, and estimates of egg mass densities, expressed as the number of new egg masses per meter square of foliage, were computed using the following procedures:

(Cluster level estimates) The sampling design established a "3-tree cluster" to be the primary sampling unit. Cluster level estimates are needed first and are used for plot averages.

(a) larval

$$X_{ijk} = \left\{ \frac{\sum_{l=1}^{t} \left(\sum_{m=1}^{b} \frac{\text{No. Budworm}}{\text{No. Buds}}_{ijklm} \times 100.0 \right)}{b} \right\}$$
$$t$$

(b) egg mass

$$X_{ijk} = \left\{ \frac{\sum_{l=1}^{t} \left(\sum_{m=1}^{b} \frac{\text{No. Egg Mass}_{ijklm}}{(L_{ijklm})\,(W_{ijklm})/200(10{,}000)} \right)}{b} \right\}$$
$$t$$

Where X_{ijk} is the cluster level estimate for either larval or egg mass densities. Subscripts and notations are defined as the following:

i = treatment	1 = treated	2 = untreated
j = subunit	j = 1, 6	
k = cluster	k = 1, 25	
l = tree	1 = 1, t (usually 3)	
m = branch	m = 1, b (usually 4 for larval sampling and 2 for egg mass sampling)	

(Subunit means and standard errors) Means and standard errors were calculated for each subunit using the following formulas:

$\bar{x}_{ij} = \sum_{k=1}^{n_{ij}} x_{ijk}/n_{ij}$, where x_{ijk} is the cluster levels estimate and $\bar{x}_{ij}$ is the mean from the j^{th} subunit from the i^{th} treatment.

$$\text{S.E. } \bar{x}_{ij} = \sqrt{\frac{\sum x_{ijk}^2 - \frac{\sum x_{ijk}^2}{n_{ij}}}{n_{ij} - 1}}$$, where S.E. $\bar{x}_{ij}$ is the standard error of the mean of $\bar{x}_{ij}$.

(Treatment level means and standard errors) Aggregate means for the treated and untreated areas were computed as follows:

$$\bar{x}_1 = \frac{\sum_{j=1}^{6} n_{ij}\,\bar{x}_{ij}}{\sum_{j=1}^{6} n_{ij}}$$, where n_{ij} is the number of clusters in each subunit.

The standard error was computed using the following formula:

$$\text{S.E. } \bar{x}_1 = \frac{\sum_{j=1}^{6} n_{ij}^2\,\text{S.E.}^2_{\bar{x}_{ij}}}{\left(\sum_{j=1}^{6} n_{ij}\right)^2}$$

(Statistical tests) Budworm densities were compared for the same year between the treated and untreated check populations, as well as comparing the densities between years for the same populations (Table 11, Appendix 2).

Hypotheses Tested:

Treated		*Untreated*
H1: year 1 = year 2		year 1 = year 2
H2: year 2 = year 3		year 2 = year 3
H3: year 1	=	year 1
H4: year 2	=	year 2
H5: year 3	=	year 3

The following results were expected from testing the hypotheses:

H3: Expect to be same
H4, H5: Expect to be different
H1, H2: For the checks, expect to be the same
H1: For treated, expect to be different
H2: For treated, expect to be same

All data were pooled for the treated and untreated areas constituting the two samples. Tests for differences between the two were extremely sensitive. The intent of the project was to be able to detect differences between the two populations and to observe the residual budworm population in the treated population over time.

Tree Damage Appraisal Phases

Evaluating Defoliation *Immediate* Defoliation on Douglas-fir was sampled on 15 clusters in each subunit in 1977 and 1978, and 25 clusters in 1979. White fir clusters were selected and sampled in eight subunits (subunits 2, 3, 4, and 5 in the treated area, and 8, 9, 10, and 11 in the untreated area) in 1977 and 1978 (Fig. 1). These clusters were adjacent to larval and egg mass sample clusters. On all clusters, three codominant Douglas-fir and white fir trees, 30 to 50 feet tall, with relatively open-grown crowns, were sampled. Defoliation data were collected only on Douglas-fir in 1979.

Sample branches consisted of four apical branches, 70 cm in length, taken from four quadrants at midcrown of each sample tree. From each of these branch samples, 25 new shoots were examined for current defoliation using the left side of one branch and the right side of another, and so on. Each new shoot was individually examined for defoliation and assigned an index value as follows:

6-class

Defoliation class %	Index value	Midpoint value %
0	0	0
1–25	1	12.5
26–50	2	37.5
51–75	3	62.5
76–99	4	87.5
100	5	100

The 6-class defoliation estimate is determined by first obtaining branch estimates, then tree estimates, then cluster estimates. The branch estimate is based on a weighted average using number of twiglets falling in each category and the midpoint value for each category. The formula is as follows:

(Branch averages)

$$DEF_{ijklm} = \frac{N_0(0) + N_1(12.5) + N_2(37.5) + N_3(62.5) + N_4(87.5) + N_5(100)}{\sum_{i=1}^{6} N_i}$$

(Cluster average)

$$\bar{x}_{ijk} = \left\{ \frac{\sum_{l=1}^{t} \left(\frac{\sum_{m=1}^{b} DEF_{ijklm}}{b} \right)}{t} \right\}$$

Long-term The same methods used to evaluate immediate defoliation were used to evaluate long-term defoliation.

Tree Mortality and Top-Kill Tree damage data were collected at five locations in each of the treated and untreated subunits, for a total of 60 sample locations. At each location, a cluster of five permanent 1/100-acre fixed radius plots were sampled. Permanent 1/100-acre plots established in 1977 were used as the center plot, and four additional plots were located 100 feet from the center of the permanent plot in cardinal directions. Trees were recorded by species and condition (live, top-killed, dead). Trees with a diameter at breast height (d.b.h.) of less than 0.5 inches or less than 4.5 feet in height were considered as seedlings. Additional categories follow: saplings, 0.5 to 4.9 inches d.b.h.; poles, 5.0 to 9.9 inches d.b.h. Trees 10 inches in diameter and larger were recorded in 1980 on variable plots (20 basal area factor) located at the same points as fixed radius plots. Pine and spruce trees also were recorded on variable plots. Data were analyzed using the PEST computer program.[1]

Monitoring

Aquatic Organisms Harry Kennedy and Charlie Sanchez, U.S. Department of the Interior, Fish and Wildlife Service, Albuquerque, New Mexico, sampled San Pablo Creek for aquatic organisms. Drift samples, using a 10-inch ring net, were taken for 10 minutes at 7:30 and 8:00 a.m. MDT at one site in 1977, 1978, and 1979. Surber square foot bottom samples were taken at one site in 1977 and 1978, and at five sites in 1979.

Aquatic organisms were identified by Dr. Manuel Molles, Department of Biology, University of New Mexico, Albuquerque, New Mexico.

Birds The occurrence of bird species was determined along a mile segment of Smokey Bear Road, subunit 3 (Fig. 1), in a forested area where carbaryl had been aerially applied. The surveys were done in the

[1] Acciavatti, Robert E., and Brian W. Geils. 1977. A user's guide to "PEST:" A computer program for summarizing forest insect and disease damage surveys. USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 77-16. 45 pp.

morning hours. A modification of the transect method described by Emlen[2] was used. Densities of breeding birds were recorded in 1977 and 1978, but only species were noted in 1979.

Parasites of the Western Spruce Budworm John Schmid, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, completed 3 years of sampling to determine the incidence of parasitism of the western spruce budworm. A minimum of 300 budworm larvae were collected in each of the treated and untreated subunits in 1979. Budworm larvae were collected during periods when they were in the 3rd–5th and 5th–6th instars. Larvae were placed in petri dishes with foliage or artificial diet, and the dishes were examined for parasites when most moths had emerged. Each parasite was identified to species, and the percent parasitism was determined for each species.

[2] Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk. 88:323–342.

Organization

Personnel from the Forest Pest Management Staff Unit, State and Private Forestry, Albuquerque, New Mexico, in cooperation with the Santa Fe National Forest, administered the project. At the peak of project operations, a total of 39 individuals were working on the project (Appendix 1). Also, there were many others working on aircraft inspections, contracting, satellite studies, or observing spray operations.

Personnel for the project were recruited from the Carson, Coronado, and Lincoln National Forests, and from Regional Office Staff Units in Region 3. In addition, valuable assistance was provided by the Methods Application Group (MAG), Davis, California, and the Missoula Equipment Development Center (MEDC), Missoula, Montana. Environmental monitoring was done by personnel from the U.S. Fish and Wildlife Service, University of New Mexico, and Museum of Northern Arizona.

Project Costs

In 1977, it was estimated that the treatment, insect sampling, tree damage sampling, and other project work for the 3-year project would cost $428,219. The actual cost, including funds contributed by the Region, was $448,894. Yearly costs follow: 1977 (treatment year), $319,387 (Table 1, Appendix 2); 1978, $60,350 (Table 2, Appendix 2); and 1979, $69,157 (Table 3, Appendix 2).

Aerial Application

Insecticide

Sevin 4 oil, a formulation of carbaryl, was applied by aerial means at a rate of one (1) pound (0.37 kg) active ingredient per acre. The tank mix, consisting of 50 percent Sevin 4 oil and 50 percent No. 2 fuel oil, was applied at 1/2 gallon per acre. Carbaryl, a carbamate insecticide, is registered for control of a wide variety of insect pests on many crops, animals, ornamental plants, forest lands, and wooded areas. Carbaryl has a long residual action and appreciable stomach action. It is available for general public use. This formulation has yielded consistent and satisfactory suppression results in the West, and, therefore, was selected for this project.

Aircraft

Since helicopters had been successfully used to apply the carbaryl formulation on previous projects, they were selected for use on this project.[3] Helicopters were considered to be more expensive than fixed-wing aircraft, but fixed-wing aircraft had not been adequately evaluated and their use would have added another variable to the project.

By contract specification, helicopters had to operate at an average altitude of 8,400 feet and spray a minimum of 1,800 acres during a normal 3-hour spray day. The treatment phase was successfully completed, mainly as a result of exceptionally favorable spraying conditions. None of the contract helicopters were able to treat 1,800 acres in 3 hours.

The spray system and difficulties associated with each helicopter follow:

Aerospatiale SA315B Lama (N47312) *Spray System* The spray system was a sling type bucket manufactured by Transland (model unknown). It had a 200-gallon fiberglass tank with a 4-inch post. The boom was round (1.5 inch outside diameter) and the overall length was 47 feet. A 7 HP Tecumseh engine was mounted on top of the tank and it drove a sump-type centrifugal pump located in the bottom of the tank. The boom pressure was manually set by a valve located between the pump and boom.

[3] Flavell, T. H., S. Tunnock, J. W. Barry, R. B. Ekblad, and W. M. Ciesla. 1975. Pilot project of carbaryl and trichlorfon against the western spruce budworm, Beaverhead National Forest, Montana, 1975. USDA Forest Serv., Northern Reg., Missoula, Montana. Report No. 78–5. 20 pp.

The pilot could start and stop the spray system engine and turn the spray on or off by controls located in the cockpit. These controls were electrically connected to the sling system controls through an electrical cord which had to be connected each time the system is hooked up to the cargo hook. This connection was very simple and fast to operate.

Difficulties The Transland sling type bucket system was in poor condition when it arrived. The engine continually failed to operate properly, even after it was replaced.

The nozzles on the sling system were located so close to the boom, when positioned at 45 degrees forward and down, that spray began to collect on the boom. This problem was solved by placing a 3-inch nipple between the boom and nozzle.

An attempt was made to raise the tip ends of the boom on the sling system 2 feet above the ground to reduce the possibility of the tips hitting the ground during take-offs and landings. However, when the tips were raised, they were inclined forward and the sling system swung radically in flight. The booms had to be lowered to their original position.

Hiller UH-12EJ3 Helicopter (N62395) *Spray System* The spray system was a hybrid, using Simplex Manufacturing Company tanks, Chadwick, Incorporated, hydraulic driven pesticide pump, and a toe mounted boom. The fiberglass tank capacity was 100 gallons and had an electric operated dump valve. The boom was about 40 inches in length. It was toe mounted and capable of being folded. It was airfoil shaped, except for 4-foot long round extensions on each end. The pump was a centrifugal-submerged type driven by a hydraulic system manufactured by Chadwick, Incorporated.

Difficulties When the pressure system was adjusted to 50 PSIG, the bypass into the bottom of the tank would squirt the spray formulation out of the tank lid when the tank was nearly empty. This was solved by rebending the deflector plate provided inside the tank for this purpose.

Hiller U-12EJ3 Helicopter (N65148) *Spray System* The system was a hybrid, using Transland 100-gallon fiberglass tanks and Chadwick, Incorporated, hydraulic driven pesticide pump. The boom length was about 48 feet and was made of aluminum. The pump was a centrifugal-submerged type driven by a hydraulic system manufactured by Chadwick, Incorporated.

Difficulties The pilot noticed that the ends of the airfoil shaped boom were creating lift which he could feel in the controls when maneuvering the helicopter. He taped a stick on the end of each boom to act as spoilers and eliminated the aerodynamic lift.

Calibration

The Lama spray system was calibrated for a speed of 70 MPH, ½ GPA. and a 200-foot swath width. This required the spray system to deliver the following flow rate:

$$\text{Flow rate (Lama)} = \frac{(\frac{1}{2}\text{ GPA})\,(70\text{ MPH})\,(200\text{ ft.})}{495} = 14.14\text{ GPM}$$

The Hiller spray systems were calibrated for a speed of 70 MPH, ½ GPA, and a 125-foot swath. This required each spray system to deliver the following flow rate:

$$\text{Flow rate (Hiller)} = \frac{(\frac{1}{2}\text{ GPA})\,(70\text{ MPH})\,(125\text{ ft.}).}{495} = 8.84\text{ GPM}$$

The number of nozzles required for the Lama spray system is based on the following: A required flow rate of 14.14 GPM; operating at a pressure of 50 PSIG; using 8006 spray tip with a flow rate of 0.67 GPM (based on water and a pressure of 50 PSIG); and a flow rate correction factor of 1.05 (1.05 is a calculated correction factor; however, the insecticide manufacturer recommended 1.1; therefore, 1.1 was used when the 8006 spray tips were replaced with 8004 spray tips).

$$\text{No. of nozzles} = \frac{\text{system flow rate}}{\text{flow rate/spray tips} \times \text{correction factor}}$$

$$= \frac{14.14\text{ GPM}}{0.67\text{ GPM/spray tip} \times 1.05}$$

$$= 20\text{ spray tips (use 20 each 8006 spray tips at 50 PSIG)}$$

The same procedure was used to calculate the number of nozzles required for the other spray systems.

Calibration of the spray systems was accomplished by installing the required number of nozzles and setting the specified boom pressure, by using a calibrated pressure gauge. While setting the boom pressure, each spray tip was observed for uniformity of spray pattern. If any were found defective, they were replaced. Also, periodically during the project, the calibration was checked by noting the time required to spray a known quantity of materials. No record of these times or quantities was kept, but the checks verified the calibration.

Characterization

Characterization trials were conducted on June 8, 1977, on a relatively flat area on Cuba Mesa, Cuba Ranger District. Temperature, humidity,

wind speed, and wind direction were continually checked during the trials. Smoke bombs were also used to show probable spray dispersal and to assist the pilot in orientation. A card line was layed at a right angle to the wind. Kromekote® deposit cards were placed at 10-foot intervals along this line. Helicopters were instructed to fly across the card line at 70 miles per hour and about 50 feet above the ground. After 10 minutes, cards were retrieved and the density and size of drops were checked. The effective spray swath of each helicopter was determined by counting cards which had at least eight drops per cm^2.

The volume median diameters (VMD's) were larger than desired for all three aircraft; however, there was no additional time to conduct further trials (Table 4, Appendix 2). The first four trials were done when conditions were acceptable for obtaining spray characterization data and the conditions were marginal for the remaining trials. Refer to Tables 5, 6, and 7, Appendix 2, for the droplet size distribution for the three aircraft.

Spray Deposit Assessment

White Kromekote® cards were used to monitor spray deposit and drift of the dyed (Automate Red B) spray around trees sampled for larval reduction, in openings, and near streams. The Quantimet image analyzer, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, was used to assess 1) droplet density (number per cm^2), and 2) VMD (μm), number mean drop diameter (μm), and mass recovery (gallons per acre).

Spray deposit data showed that there was adequate coverage of sample trees even though the drop density was low and the VMD was large (Table 8, Appendix). The VMD on spray blocks was considerably higher than sizes estimated during characterization trials. Spraying System Flat Fan 8006 spray nozzles were used on subunits 5 and 6. In an effort to get a smaller droplet size, 8004 nozzles were used on subunits 1 to 4. The excessively large sizes in all subunits apparently were the results of leaks in the spray systems. Also, estimates of mass recovery figures exceeded the planned application rate of ½ gallon per acre in 9 of the 12 sites sampled. Records of gallons loaded into the spray helicopters and sprayed on the subunits, however, show that these data are incorrect. The discrepancy may be explained, in part, by the uneven distribution of spray over treated areas, and by the large drops observed on many cards. The methods of estimating mass deposit assumes a logarithmic normal distribution of drop sizes.

Spray drift reached all streams in the treatment area, and a minute amount of spray reached the parking lot just south of the San Pedro Parks Wilderness.

Meteorological Conditions

The weather was favorable for spraying from June 10 through 19. Winds aloft were light, morning temperatures were moderate, and only scattered thunderstorms occurred in the afternoon hours.

Results

Entomological Phases

Larval Densities Following treatment, the larval density per 100 buds of new foliage on Douglas-fir remained at a low level from 1977 to 1979. An average of 14.9 larvae was recorded during the 1977 pre-spray sample, about one larvae per 100 buds remained 14 days following treatment, and the pre-spray density decreased to 0.9 in 1978 and 0.6 in 1979 (Table 9, Appendix 2).

In the untreated area, the infestation decreased from 10.8 larvae per 100 buds of Douglas-fir to 8.6 larvae in 1978. A slight increase in the larval density to 8.9 was noted in 1979 (Table 9, Appendix 2). Overall, the average density of larvae in the untreated area was significantly higher than in the treated area for all 3 years that samples were taken (Fig. 2).

Larval densities per 100 buds of new foliage increased significantly in the treated and untreated areas in 1980: treated area, 1.2; untreated area, 17.5. Although the average density of larvae was low in the treated area, light to moderate defoliation was detected in portions of subunits 2, 3, and 4 during the 1980 aerial survey.[4]

Egg Mass Densities The density of egg masses was another population index that indicated that suppression of the budworm population was achieved from 1977 to 1979. In the treatment area, the average density of egg masses per square meter of foliage decreased from 1.6 in 1977 to 0.4 in 1978, and increased slightly to 0.7 in 1979 (Table 10, Appendix 2). The average density of egg masses per meter square of foliage in the untreated areas was: 1977, 9.8; 1978, 10.0; and 1979, 15.7. A marked increase in the average density of egg masses was noted in the untreated area in 1979 (Fig. 3). This increase in the density of eggs indicated that defoliation would be heavier in the untreated area in 1980. Conversely, the infestation was expected to remain at a low level in the treated area in 1980. Both of these infestation predictions were verified in 1980.

Statistical Tests A comparison of average larval and egg mass densities shows that the differences between treated and untreated check areas for each sampling period are highly significant (Table 11, Appendix 2). Although an attempt was made to select subunits with similar larval densities, the 1977 pre-spray larval densities were more variable in the untreated check subunits, and the average density of

[4] Sampling will be done yearly until the densities of insects reach a high level in treatment area or until the infestation collapses.

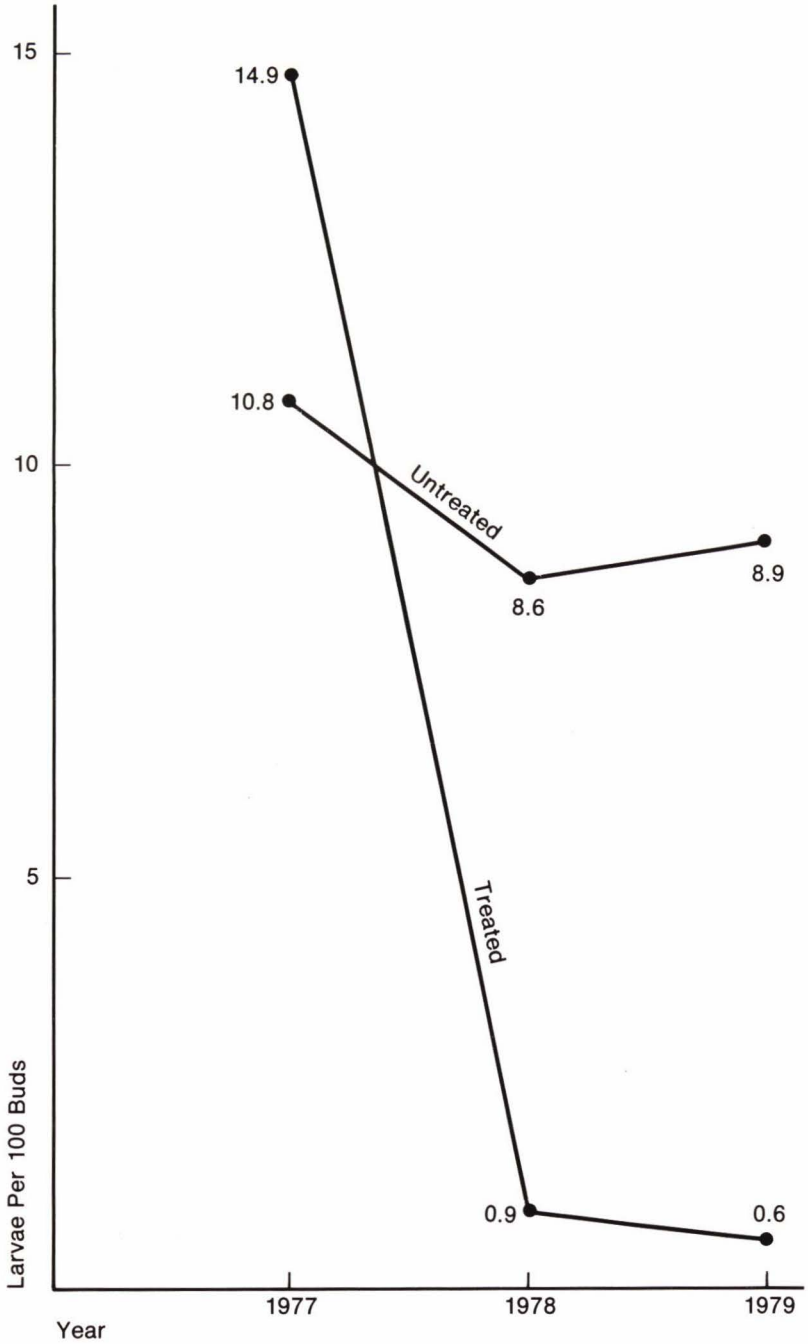


Figure 2.—Comparison of average number of western spruce budworm larvae in treated and untreated areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico (Table 9, Appendix 2).

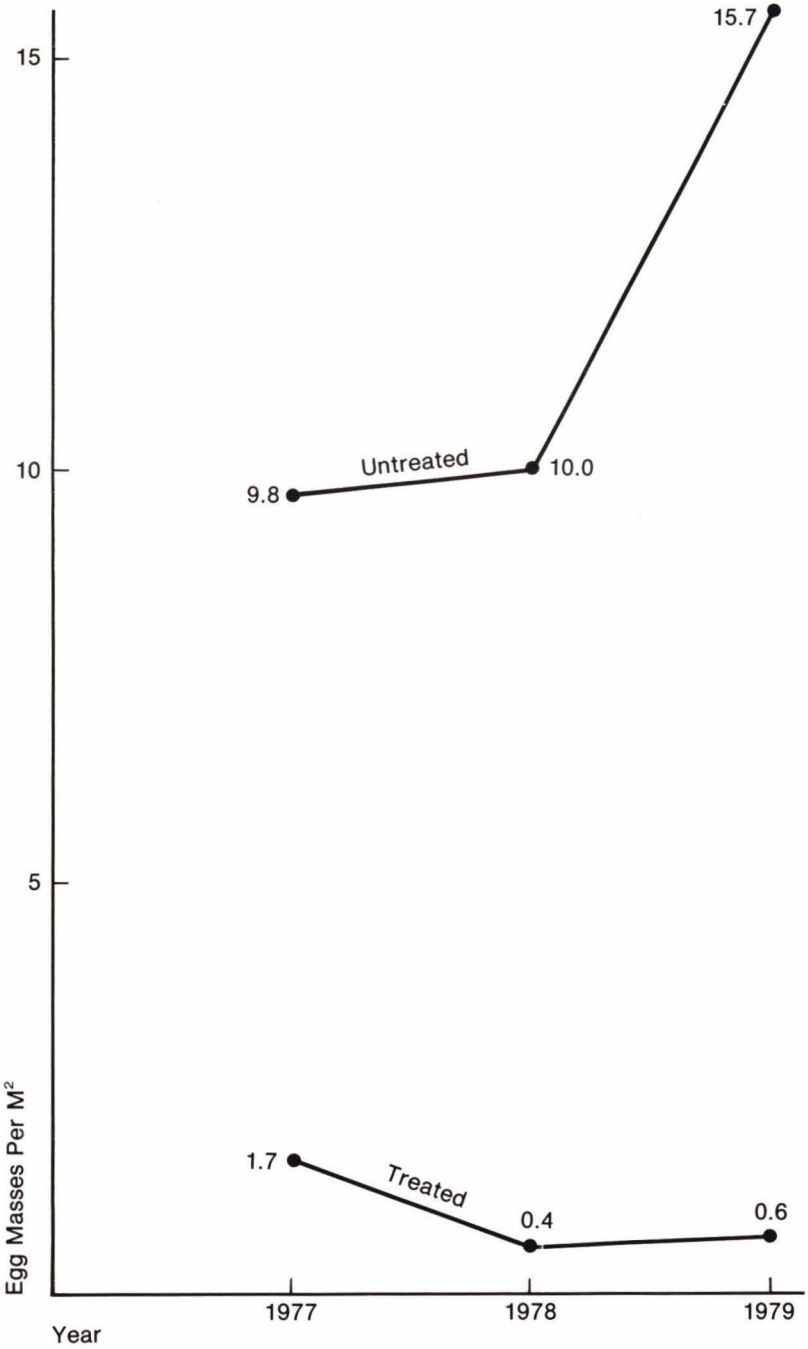


Figure 3.—Comparison of average number of western spruce budworm egg masses in treated and untreated areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico (Table 10, Appendix 2).

larvae was lower than in the treatment subunits. However, the desired results were achieved for the 1978 and 1979 pre-spray sample period, i.e., the larval densities in the treated area were much lower than in the untreated area.

Differences in larval densities within treated and untreated areas and egg mass densities within treated and untreated areas varied from being not significant to highly significant (Table 11, Appendix 2).

Tree Damage Appraisal Phase

Defoliation A comparison between defoliation in treated and untreated areas for white fir in 1977 and 1978 and Douglas-fir from 1977 to 1979 showed that foliage protection was achieved in the treatment area (Table 12, Appendix 2, and Fig. 4). Even in the treatment year of 1977, when 20 percent of the budworm larvae were in the fifth and sixth instars, the average protection of foliage was about 40 percent for white fir and 35 percent for Douglas-fir. The amount of foliage protected in 1978 was even greater: white fir, 89 percent; Douglas-fir, 90 percent. In 1979, defoliation was measured only on Douglas-fir, and the percent of foliage protected was 91 percent.

Other Tree Damages Top-killing and mortality of understory trees was recorded in 1979, but the amount of damage in the untreated subunits was low and about the same as the treated subunits.

Permanent plots will continue to be sampled in the future to follow tree damages that may occur between treated and untreated areas later in the infestation cycle.

Monitoring

Aquatic Organisms In 1977, populations of aquatic insects were reduced when a portion of San Pablo Creek was oversprayed. Follow-up sampling done at one site in June 1978, 1 year following treatment, indicated the number of organisms was similar to the pre-spray level, but recovery of some species had not occurred (Table 13, Appendix 2). Insects in the families Chloroperlidae, Nemouridae, Lepidostomatidae, Limnephilidae, Stratiomyiidae, and Tipulidae were not found. In 1979, Surber bottom sampling was done at the same sites and several new sites, and specimens in all families were collected (Table 14, Appendix 2). Although carbaryl is highly toxic to many aquatic insects, it is apparent that the effects of even a direct application on a small, low-flow creek are temporary and species diversity is not adversely affected.

Birds The diversity of bird species in the treated area was not

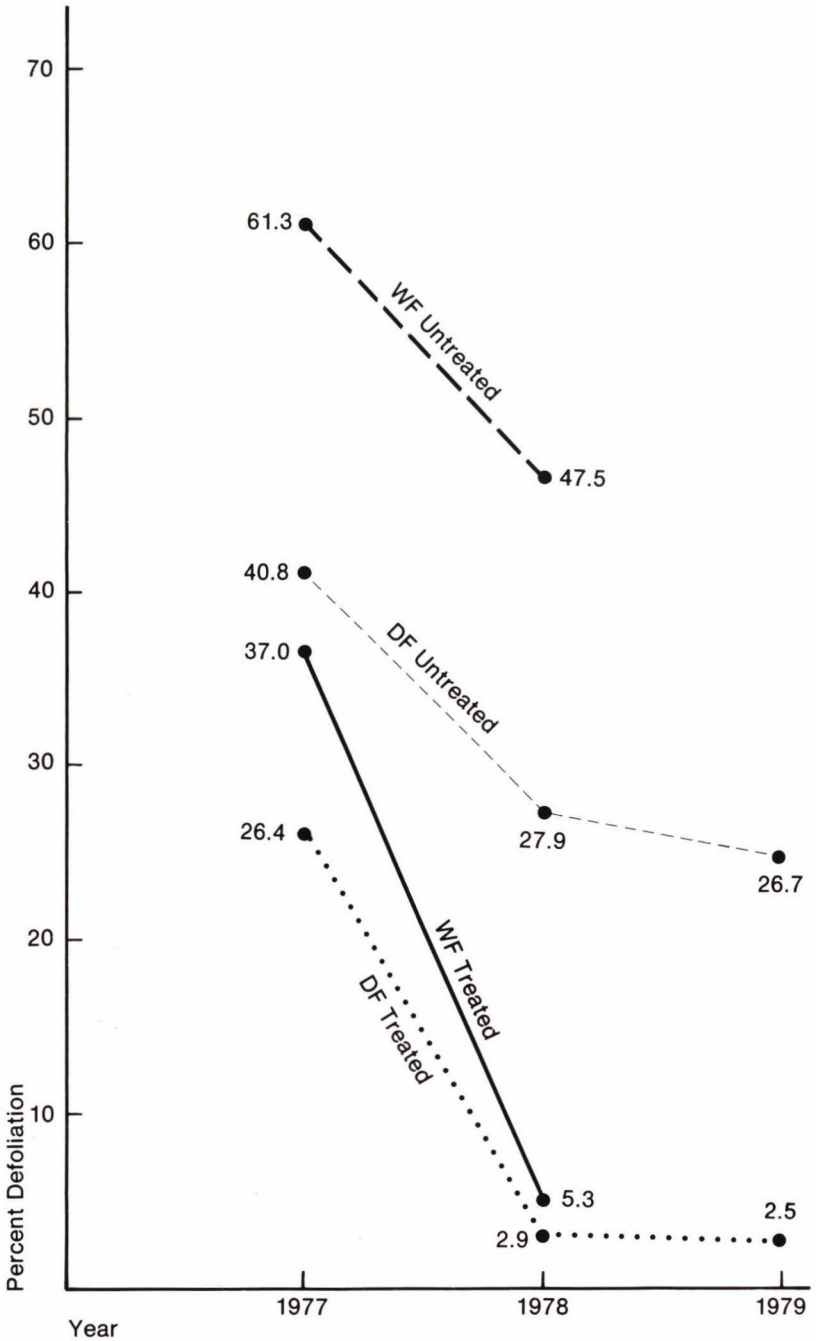


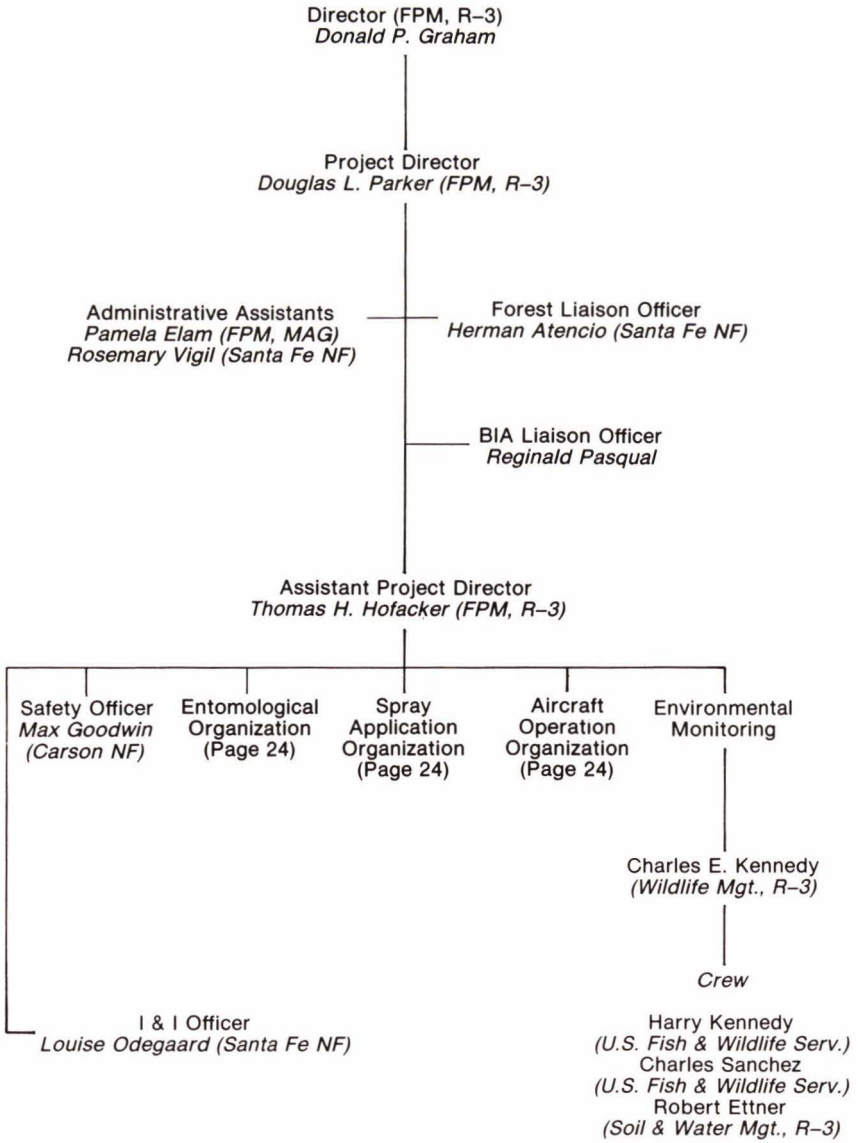
Figure 4.—Comparison of average western spruce budworm-caused defoliation of Douglas-fir (DF) and white fir (WF) in treated and untreated areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico (Table 12, Appendix 2).

adversely affected by the aerial application of carbaryl. Prior to treatment in 1977, 40 species of birds were recorded on sample transects. Twenty-five species were observed in 1978; however, the sampling period was shorter, and rainy conditions were encountered when transects were run, which would cause birds to be less active. Almost all of the bird species observed in 1977 were sighted in 1979. The Great-horned owl, Pygmy owl, and Lesser nighthawk were not observed in either 1978 or 1979, probably because transects were done in the early morning hours. However, these birds were seen in the treatment area following treatment in 1977. Refer to Table 15, Appendix 2, for information on the occurrence of bird species in the treatment area in 1977, 1978, and 1979.

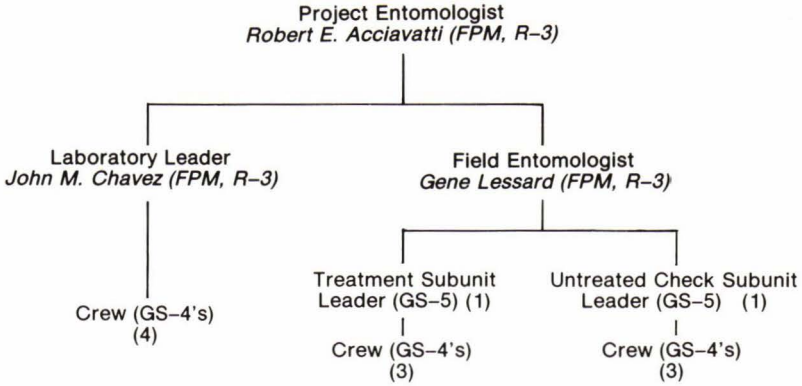
Insect Parasites of the Western Spruce Budworm The percent parasitism by insect parasites in the treatment year and two subsequent years showed that some species increased while others decreased. Overall, most species were not significantly affected as a result of the aerial application of carbaryl. *Glypta fumiferanae* (Ichneumonidae) decreased significantly in the sprayed areas, while another ichneumonid parasite, *Phytodietus fumiferanae,* increased in the same areas. *Apanteles fumiferanae* (Braconidae) increased significantly in two of the treated areas the first year after spraying, but densities were about the same in treated and untreated areas in 1979. Other parasites decreased the first year following treatment, but their numbers were comparable to untreated areas the second year following treatment. Numbers of several parasites were too low to determine any trend in percent parasitism.

Appendix 1

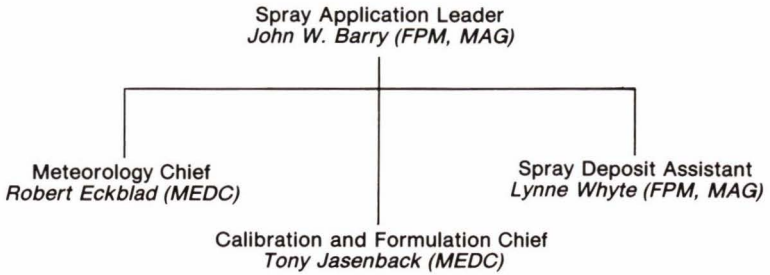
Organization Charts



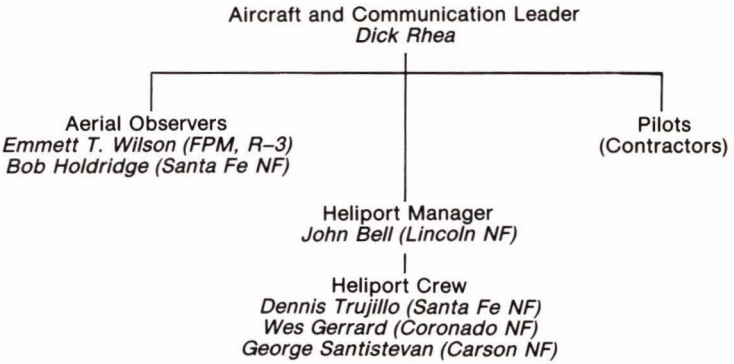
Western spruce budworm suppression and evaluation project organization, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.



Entomological organization for the western spruce budworm suppression and evaluation project, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.



Spray application organization for the western spruce budworm suppression and evaluation project, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.



Aircraft operation organization for the western spruce budworm suppression and evaluation project, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Appendix 2

Table 1—Actual expenditures by budget item in the treatment year (1977), Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Item	F.Y. 1977 (dollars) Project
Aircraft	
Spray helicopters ($2.20/acre)	$ 81,480
Chase helicopters ($125.00/hour)	6,400
Aircraft rentals	1,440
Total	$ 89,321
Pesticide	
Sevin* 4 oil (bulk $8.25/gal.; drums, $8.80/gal; tanker, $288.00/day)	$83,965
Oil carrier ($0.42/gal.)	4,200
Automate Red B dye ($492.00/30-gal. drum)	3,936
Total	$ 92,101
Rental Equipment and Supplies	
Vehicles	$ 13,477
Headquarters and cooler	912
Furniture	229
Other	500
Total	$ 15,118
Equipment and Supplies	$ 13,122
Personnel	$ 40,398
Administrative	$ 40,415
Services and Overhead	$ 28,912
Total	$319,387

Table 2—Expenditures by budget item in the year following treatment (1978), Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Item	F.Y. 1978 (dollars) Project	Contributed	Total
Vehicles			
5, GSA, ½-ton pickups, 4-speed, 4×2, 6-cylinder, with 2,000 miles of use per month for 3.5 months at $220 per vehicle per month.	$ 3,050	$ 0	$ 3,050
1, GSA, ½-ton pickup, 4-speed, 4×2, 6-cylinder, 2,000 miles per month for 3.5 months.	900	0	900
1, GSA van, 2,000 miles per month for 1 month.	300	0	300
Subtotals	$ 3,050	$ 0	$ 3,050
Equipment and Supplies			
Field sampling and laboratory equipment (tree paint, alcohol preservative, map copying, printing, etc.)	$ 1,000	$ 0	$ 1,000
Laboratory facility (compressor for second walk-in cooler, modify TM inventory room for cooling, paint).	0	1,000	1,000
Camp equipment and supplies (repair tents, tables, stoves, cooking gear, ice chests, etc.)	1,000	600	1,600
Seligman Girl Scout Camp leasing for 3.5 months.	2,000	0	2,000
Subtotals	$ 4,000	$ 1,600	$ 5,600
Personnel			
2 subunit leaders, GS–404–5 (85 days @ $38.32 per day per leader) (temporary position for project)	$ 6,500	$ 0	$ 6,500
6 crew members, GS–404–4 (85 days @ 34.24 per day per crew member) (temporary positions with project)	17,500	0	17,500

Item	F.Y. 1978 (dollars) Project	Contributed	Total
Personnel, cont.			
2 crew members, GS–404–4 (50 days @ $34.24 per day per crew member) (temporary positions with FPM)	0	3,400	3,400
Mike, laboratory leader, GS–404–5 (85 days @ $42.16 per day)	0	3,600	3,600
Bob, project entomologist, GS–414–11 (85 days @ $79.60 per day)	0	3,800	3,800
Subtotals	$24,000	$10,800	$34,800
Administrative			
Per diem for 8 project temporaries ($10/day per person, camp rate for 85 days)	$ 6,800	$ 0	$ 6,800
Per diem for 2 FPM temporaries ($10/day per person, camp rate for 50 days)	1,000	0	1,000
Per diem for 2 FPM permanents (Mike & Bob, $10/day per person, camp rate for 85 days)	1,700	0	1,700
Overtime for pre-spray sampling (10-hour days for 10 straight days, including 2 weekends, for 12 people)	4,600	0	4,600
Subtotals	$14,100	$ 0	$14,100
Service			
Data analysis	$ 500	$ 0	$ 500
Overhead (R–3 at 5 percent in F.Y. 1978)	2,300	0	2,300
Subtotals	$ 2,800	$ 0	$ 2,800
Grand Total	$47,950	$12,400	$60,350

Table 3—Expenditures by budget item for the second year following treatment (1979), Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Item	F.Y. 1979 (dollars) Project	Contributed	Total
Vehicles			
4, ½-ton pickups, 4-speed, 4×2, 6-cylinder, with 2,000 miles of use per month for 3.5 months at $350.00 per vehicle per month	$ 5,600	$ 0	$ 5,600
Gasoline receipts for 4 vehicles at $250.00 per month	1,000	0	1,000
1, ½-ton pickup, 4-speed, 4×4, 8-cylinder, with 2,000 miles of use per month for 3.5 months at $320.50 per month.	0	1,125	1,125
1, ½-ton pickup, 4-speed, 4×2, 8-cylinder, with 2,000 miles per month for 3.5 months at $255 per month.	0	892	892
Subtotal	$ 6,600	$ 2,017	$ 8,617
Equipment and Supplies			
Field sampling and laboratory equipment (tree paint, alcohol preservative, map copying, printing, etc.)	$ 800	$ 0	$ 800
Trailer rental for lab space	700	0	700
Seligman Girl Scout Camp, or other facility, leasing for 3.5 months	2,000	0	2,000
Subtotal	$ 3,500	$ 0	$ 3,500
Personnel			
2 subunit leaders, GS–404–5, temporary position for project (95 days at $40.24 per day per leader)	$ 7,700	$ 0	$ 7,700
6 crew members, GS–404–4, temporary position for project (95 days at $35.95 per day per crew member)	20,500	0	20,500

Item	F.Y. 1979 (dollars) Project	Contributed	Total
Personnel, cont.			
2 crew members, GS–404–4, temporary position with FPM, (50 days at $35.95 per day per crew member)	0	3,600	3,600
Field and laboratory leader, GS–404–5 (95 days at $44.27 per day)	0	4,200	4,200
Project entomologist, GS–414–11 (95 days at $78.62 per day)	0	7,500	7,500
Subtotal	$28,200	$15,300	$43,500
Administrative			
Per diem for 8 project temporaries ($10/day per person camp rate for 70 days)	$ 5,600	$ 0	$ 5,600
Per diem for 2 FPM temporaries ($10/day per person camp rate for 25 days)	500	0	500
Per diem for 2 FPM permanents (Gene & Mike, $10/day camp rate for 70 days per person)	0	1,400	1,400
Overtime for pre-spray sampling (10-hour days for 10 straight days including 2 weekends for 12 people)	2,200	740	2,940
Subtotal	$ 8,300	$ 2,140	$10,440
Service			
Data Analysis	$ 0	$ 500	$ 500
Overhead (R–3 at about 5 percent in F.Y. 1979)	2,400	0	2,400
Subtotal	$ 2,400	$ 500	$ 2,900
Grand Total	$49,000	$19,957	$69,157

Table 4—Spray aircraft characterization trials, June 8, 1977, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Aircraft [a]	Trial [b]	Time	Temperature (°F)	RH (%)	Field VMD (μm)	Swath width (Feet)	Boom pressure (PSIG)
Hiller N65148	1	0608	47	64	280	140–180	44
Hiller N62395	2	0629	45	68	362	160–180	—
Hiller N65148	3	0649	50	66	319	180–200	50
Hiller N62395	4	0705	54	49	290–328	200–240	50
Hiller N65148	5	0737	60	57	309	180	50
Lama N47312	6	0755	65	49	346	160–180	—
Lama N47312	7	0907	70	42	328	—	50
Lama N47312	8	0926	75	39	350	60	50
Hiller N65148	9	0944	78	35	280	160	50

[a] Spray nozzle Spraying System Flat Fan 8006. Release height varied by trial from 50′ to 125′ above deposit cards. Aircraft speed 70 miles per hour.

[b] Meteorological conditions were marginal for trials 5–9.

Table 5—Size distribution of Sevin® 4 oil spray droplets from Lama 315B with a slung bucket system, and Spraying Systems 8006 nozzle tips, characterization trials, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Drop size category (μm)	Percent by drop size	Cumulative %
39.1	13	13
74.2	13	26
109.6	14	40
142.1	13	53
174.9	13	65
209.4	9	74
241.7	6	80
273.4	5	85
304.8	3	87
334.7	2	89
367.0	2	90
397.1	1	92
421.7	1	92
477.9	4	96
543.2	2	98
740.8	2	100

Table 6—Size distribution of Sevin® 4 oil spray droplets from Hiller N62395 with Spraying Systems 8006 nozzle tips, characterization trials, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Drop size category (μm)	Percent by drop size	Cumulative %
39.1	16	16
74.2	13	29
109.6	15	44
142.1	14	58
174.9	13	71
209.4	8	79
241.7	6	85
273.4	4	89
304.8	3	92
334.7	2	94
367.0	1	95
397.1	.7	96
421.7	.8	97
477.9	1	98
543.2	8	99
740.8	2	100

Table 7—Size distribution of Sevin® 4 oil spray droplets from Hiller N65148 with Spraying Systems 8006 nozzle tips, characterization trials, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Drop size category (μm)	Percent by drop size	Cumulative %
39.1	16	16
74.2	13	29
109.6	12	41
142.1	11	52
174.9	11	63
209.4	8	71
241.7	5	76
273.4	5	81
304.8	4	85
334.7	3	88
367.0	2	90
397.1	2	92
421.7	.7	93
477.9	3	96
543.2	2	98
740.8	3	100

Table 8—Summary of spray deposit data, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Spray subunit [a]	Drops per cm^2	VMD [b] (μm)	NMD [c] (μm)	Mass recovery gallons/acre
1 Trees	2.95	540	198	.54
Open	9.03	478	161	.83
2 Trees	3.19	483	188	.40
Open	9.05	385	95	.22
3 Trees	3.83	508	204	.61
Open	8.67	547	253	2.30 [d]
4 Trees	4.35	541	198	.73
Open	8.83	503	174	1.06 [d]
5 Trees	5.68	546	192	.87
Open	6.6	548	182	.93
6 Trees	2.2	557	185	.31
Open	3.84	540	184	.53

[a] Spraying System Flat Fan 8004 spray nozzles were used on subunits 1–4 and 8006 spray nozzles were used on subunits 5 and 6.

[b] VMD = volume median diameter.

[c] NMD = number mean drop diameter.

[d] High recovery rates, in excess of the amount applied, probably are due to dripping of large drops from spray systems. Cards beneath trees would have a lower incidence of large drops because they are scavenged by branches.

Table 9—Western spruce budworm larvae per 100 buds on Douglas-fir for 1977 pre- and post-spray samples and 1978–79 pre-spray samples, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

		Budworm larvae per 100 buds							
		1977 Pre-spray [a]		1977 Post-spray		1978 Pre-spray [a]		1979 Pre-spray [a]	
Subunit	No. of plots	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Treated									
1	25	20.5	2.5	1.7	0.4	1.3	0.4	0.3	0.1
2	25	11.9	2.1	0.7	0.2	0.4	0.1	0.5	0.2
3 [b]	25	11.7	1.7	1.1	0.3	0.4	0.1	1.0	0.3
4	25	17.9	2.2	1.0	0.2	1.2	0.4	0.7	0.2
5	25	18.2	2.8	1.1	0.4	1.5	0.7	0.1	0.1
6	25	9.0	1.1	0.6	0.2	0.6	0.2	0.9	0.2
Average		14.9	0.9	1.0	0.1	0.9	0.2	0.6	0.1
Untreated									
7	25	2.7	0.4	0.8	0.2	2.0	0.4	1.4	0.3
8	25	9.5	1.8	5.8	1.0	10.7	2.0	11.8	1.9
9 [c]	25	8.7	1.5	4.6	0.8	11.8	1.7	11.2	1.3
10 [d]	22	17.7	3.0	7.8	1.2	11.5	1.4	10.6	1.5
11	25	12.6	2.1	8.3	1.5	10.8	1.3	9.2	1.1
12	25	14.3	2.2	8.1	1.2	5.5	0.8	9.7	1.7
Average		10.8	0.9	5.9	0.5	8.6	0.6	8.9	0.6

[a] 1977 and 1978 pre-spray samples were taken when 20 percent of the larvae were in the 5th and 6th instars, and before 5 percent had pupated.

[b] 20 plots sampled in 1978.

[c] 22 plots sampled in 1978.

[d] 3 plots destroyed by fire in 1977.

Table 10—Western spruce budworm suppression-evaluation project egg mass densities, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

	Egg Masses per m^2					
	1977		1978		1979	
Subunits	Mean	S.E.	Mean	S.E.	Mean	S.E.
Treated						
1 San Miguel	4.2	1.1	0.9	0.3	0.7	0.3
2 Joaquin	1.4	0.5	0.0	0.0	0.2	0.1
3 Smokey Bear	0.2	0.1	0.2	0.1	0.4	0.2
4 Trail	1.9	0.6	0.6	0.2	1.2	0.4
5 Blue Bird	1.2	0.4	0.4	0.2	0.8	0.3
6 Red Top	1.0	0.3	0.5	0.2	0.6	0.3
Average	1.6	0.3	0.4	0.1	0.7	0.1
Untreated						
7 Ojitos	1.0	0.3	1.0	0.3	1.5	0.6
8 Lake Fork	7.5	1.7	11.2	2.6	17.9	3.7
9 Cochiti	11.6	2.9	12.4	2.5	21.0	5.2
10 Capulin	14.4	2.5	12.5	1.9	19.2	3.3
11 Am. Springs	7.4	1.1	11.1	1.7	15.0	2.8
12 Los Alamos	17.5	2.6	12.5	1.9	20.6	3.2
Average	9.8	0.9	10.0	0.9	15.7	1.4

Table 11—Statistical tests comparing average insect densities between and within treated and untreated areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Hypothesis	X_1	X_2	t [a]	Conclusion [b]
Larvae				
1977 Pre-spray (treated area) = 1977 Pre-spray (untreated area)	14.9	10.8	3.19	HS
1977 Post-spray (treated area) = 1977 Post-spray (untreated area)	1.0	5.9	−9.88	HS
1978 Pre-spray (treated area) = 1978 Pre-spray (untreated area)	0.9	8.6	−12.02	HS
1979 Pre-spray (treated area) = 1979 Pre-spray (untreated area)	0.6	8.9	−19.71	HS
1977 Pre-spray (treated area) = 1978 Pre-spray (treated area)	14.9	0.9	31.00	HS
1978 Pre-spray (treated area) = 1979 Pre-spray (treated area)	0.9	0.6	1.82	NS
1977 Pre-spray (untreated area) = 1977 Pre-spray (untreated area)	10.8	8.6	2.02	S
1978 Pre-spray (untreated area) = 1979 Pre-spray (untreated area)	8.6	8.9	−0.31	NS
Egg Mass				
1977 Treated = 1977 Untreated	1.6	9.8	−8.48	HS
1978 Treated = 1978 Untreated	0.4	10.0	−11.25	HS
1979 Treated = 1979 Untreated	0.7	15.7	−10.27	HS
1977 Treated = 1978 Treated	1.6	0.4	4.44	HS
1978 Treated = 1979 Treated	0.4	0.7	−1.64	NS
1977 Untreated = 1978 Untreated	9.8	10.0	−0.17	NS
1978 Untreated = 1979 Untreated	10.0	15.7	3.39	HS

[a] $t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{x}_1 - \bar{x}_2}}$, where $\bar{x}_1$ and $\bar{x}_2$ are combined means from treated and untreated subunits, and $s_{\bar{x}_1 - \bar{x}_2}$ is the standard error of the difference of the means.

[b] HS = Highly Significant
NS = Not Significant
S = Significant

Table 12—Percent defoliation by subunit for Douglas-fir, 6-class system, Santa Fe National Forest and Jemez Pueblo lands, New Mexico.

Subunit	Percent Defoliation 1977 WF	1977 DF	1978 WF	1978 DF	1979 DF
Treated					
1 San Miguel	—	41.6	—	4.5	3.7
2 Joaquin	28.6	19.9	3.1	1.5	2.0
3 Smokey Bear	24.8	18.0	5.2	1.1	1.0
4 Trail	53.1	37.0	7.2	5.4	2.2
5 Blue Bird	41.8	25.8	5.7	2.7	3.0
6 Red Top	—	16.6	—	2.0	3.2
Average	37.0	26.4	5.3	2.9	2.5
Untreated					
7 Ojitos	—	14.1	—	9.4	6.8
8 Lake Fork	62.2	51.1	58.1	40.9	34.1
9 Cochiti	52.8	37.2	46.8	35.3	29.4
10 Capulin	63.6	51.2	38.7	29.0	28.3
11 Am. Springs	66.4	34.2	46.3	29.1	31.6
12 Los Alamos	—	56.7	—	23.8	29.9
Average	61.3	40.8	47.5	27.9	26.7

Table 13—Total number of aquatic organisms collected during two 10-minute drift samples taken at 7:30 and 8:00 a.m. MDT at one site in San Pablo Creek, Santa Fe National Forest, New Mexico, 1977 to 1979.

Organism	10-Minute Drift Samples			
	Pre-treatment June 1977	Treatment Day June 1977	Post-treatment June 1978	Post-treatment July 1979
Ephemeroptera				
Baetidae	4	355	1	5
Heptageniidae		110		4
Siphlonuridae		4		1
Plecoptera				
Chloroperlidae	2	84		1
Nemouridae	1	2748		
Perlidae		1		
Perlodidae		6		
Hemiptera				
Veliidae	1			1
Trichoptera				
Lepidostomatidae		98	1	
Lemnephilidae	2	50		
Coleoptera				
Hydroscapidae				1
Elmidae		6		
Diptera				
Chironomidae	1	13	1	
Dixidae		15		
Simulidae	3	22		7
Stratiomyidae				2
Tipulidae		194		
Collembola				
Acari				
Turbellaria	1	4	21	5
Unidentified		4	2	1
Total	15	3714	26	28

Table 14—Total number of aquatic organisms collected from Surber square foot bottom samples taken at 1:00 p.m. MDT in San Pablo Creek, Santa Fe National Forest, New Mexico.

Organism	Surber Bottom Samples				
	Pre-treatment [a] June 1977	Treatment Day [a] June 1977	Post-treatment [a] July 1977	Post-treatment [a] June 1978	Post-treatment [b] July 1979
Ephemeroptera					
Baetidae		25		3	73
Heptageniidae		7		3	38
Siphlonuridae					
Plecoptera					
Chloroperlidae	2				
Nemouridae	35	7			25
Perlidae		56			3
Perlodidae				1	
Hemiptera					
Veliidae				2	4
Trichoptera					
Lepidostomatidae	6				4
Lemnephilidae	2	1			2
Coleoptera					
Hydroscapidae				11	
Elmidae	61	48	9	23	28
Dryopidae			1		
Hydrophilidae					5

Diptera					
Chironomidae	10	52		31	8
Dixidae	1				4
Simulidae				12	4
Stratiomyidae	10	7			2
Tipulidae	5	1		3	
Collembola				1	
Hydracarina		1		6	
Turbellaria	10	10	19	64	78
Nematoda		1			2
Pelecypoda				6	3
Unidentified				2	2
Total	142	216	29	168	285

[a] Data collected at one site.

[b] Data collected at five sites.

Table 15—Species of birds seen in the area treated with carbaryl in 1977, Santa Fe National Forest, New Mexico.

		Results[a]		
Common Name	*Species*	*1977*	*1978*	*1979*
Turkey Vulture	*Cathartes aura*	P	—	P
Cooper's Hawk	*Accipiter cooperii*	P	—	P
Turkey	*Meleagris gallopavo*	P	—	P
Mourning Dove	*Zenaidura macroura*	P	—	P
Great Horned Owl	*Bubo virginianus*	P	—	P
Pygmy Owl	*Glaucidium gnoma*	P	—	—
Lesser Nighthawk	*Chordeiles acutipennis*	P	—	—
Rufous Hummingbird	*Selasphorus rufus*	P	—	P
Broad-tailed Hummingbird	*Selasphorus platycercus*	P	—	P
Red-shafted Flicker	*Colaptes auratus*	P	P	P
Williamson's Sapsucker	*Sphyrapicus thyroideus*	P	P	P
Hairy Woodpecker	*Dendrocopos villosus*	P	P	P
Northern Three-toed Woodpecker	*Picoides tridactylus*	P	—	P
Empidonax species	*Empidonax* sp.	P	P	P
Western Wood Pewee	*Contopus sordidulus*	P	P	—
Violet-green Swallow	*Tachycineta thalassina*	P	—	P
Steller's Jay	*Cyanocitta stelleri*	P	P	P
Common Raven	*Corvus corax*	P	P	P
Clark's Nutcracker	*Nucifraga columbiana*	P	P	P
Mountain Chickadee	*Parus gambeli*	P	P	P
White-breasted Nuthatch	*Sitta carolinensis*	P	P	P
Red-breasted Nuthatch	*Sitta canadensis*	P	P	—
Pygmy Nuthatch	*Sitta pygmaea*	P	—	P
House Wren	*Troglodytes aedon*	P	P	P
American Robin	*Turdus migratorius*	P	P	P
Hermit Thrush	*Hylocichla guttata*	P	P	P
Western Bluebird	*Sialia mexicana*	P	P	P
Townsend's Solitaire	*Myadestes townsendi*	P	P	P
Golden-crowned Kinglet	*Regulus satrapa*	P	P	P
Ruby-crowned Kinglet	*Regulus calendula*	P	P	P
Warbling Vireo	*Vireo gilvus*	P	P	P
Orange-crowned Warbler	*Vermivora celata*	P	—	P
Audubon's Warbler	*Dendroica coronata*	P	P	P
Western Tanager	*Piranga ludoviciana*	P	P	P
Black-headed Grosbeak	*Pheucticus melanocephalus*	P	—	P
Evening Grosbeak	*Hesperiphona vespertina*	P	P	—
Pine Siskin	*Spinus pinus*	P	—	P
Gray-headed Junco	*Junco hyemalis*	P	P	P
Chipping Sparrow	*Spizella passerina*	P	P	P

[a] Present (P), not observed (—).

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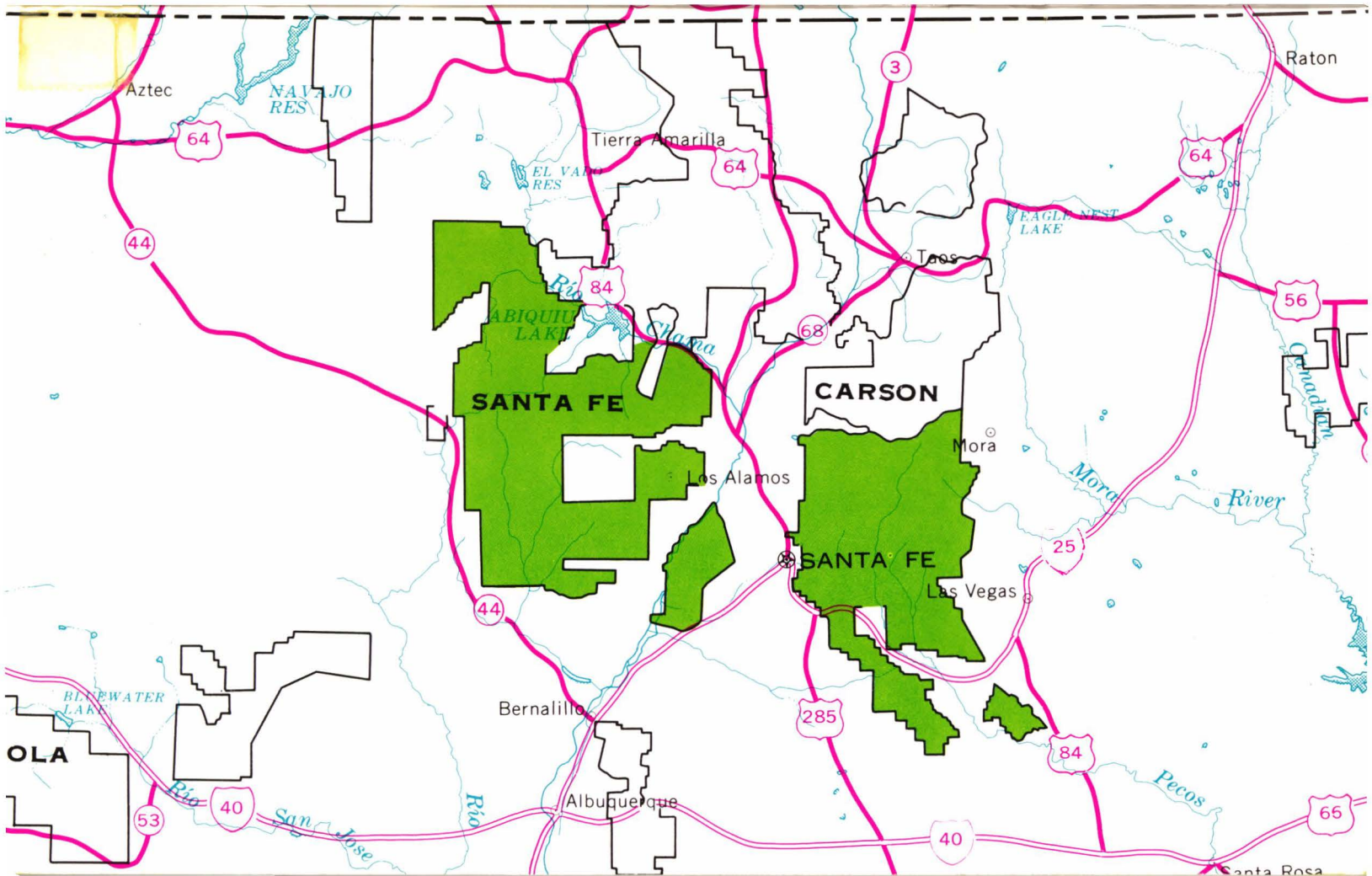
Aztec
NAVAJO RES
64
44
Tierra Amarilla
EL VADO RES
64
3
Raton
64
EAGLE NEST LAKE
Taos
84
ABIQUIU LAKE
Rio Chama
68
56
Canadian
SANTA FE
CARSON
Mora
Los Alamos
Mora River
SANTA FE
Las Vegas
25
44
BLUEWATER LAKE
OLA
Bernalillo
285
84
Pecos
53
40
Rio San Jose
Rio
Albuquerque
40
65
Santa Rosa